Deployment of Ocean Explorer and Autosub in Scottish Waters for Langmuir Cells and Internal Wave Study

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LONG-TERM GOALS

The long-term goals of this proposal are to seek a better understanding about modeling and predicting littoral ocean processes and to further enhance the autonomous underwater vehicle sampling technology through a collaborative effort with the AUV team at Southampton Oceanography Center, UK.

OBJECTIVES

The scientific objectives are to both study Langmuir circulation in coastal environment using FAU's AUV, the Ocean Explorer (OEX), and SOC's Autosub, and to study internal wave mechanism using in-situ flow and density measurement sensors on the OEX and side-scan sonar on Autosub. Results from these studies will not only form an experimental database, enabling dynamic ocean models to be characterized, validated and simulated, but also validate the FAU turbulence measurement platform by making corroborative measurement with an independent system provided by the SOC.

The technical objectives with the SOC involve co-operating on the development of 1) an intelligent distributed control system (IDCS) concept which addresses inter-operability and portability aspects at the component level between the OEX and Autosub, 2) multiple sensor data fusion algorithms which supports high-precision long-duration survey missions, and 3) mission script, data management and visualization.

APPROACH

In order to study Langmuir circulation, the Autosub, with its upward-looking sonar, will move at a depth of 20m and track the OEX coasting at depth of 3-10m beneath the Langmuir cells and traveling through the downward plumes at the location of the windrows. The turbulence measurement platform mounted on the OEX's payload consists of 2 shear probes, a pressure probe and fast thermistor whereas the OEX provides the ADCP, CTD from onboard sensors. The sonar which will be mounted on the Autosub is a 248KHz, two-component, upward-looking system. Initial flow measurement of Langmuir circulation will be carried out at a location further away from the outflow of Loch Etive, where salinity stratification is somewhat weaker and apparently does not significantly limit the penetration depths of the bubbles. A future study may consider measurements at the outflow region of

Loch Etive in strong winds to determine the effect of density stratification on Langmuir circulation. The study of internal waves will involve similar mode of operation with the Autosub measuring salinity fronts and other large scale structures and the turbulence package on the OEX measuring small-scale turbulence generated by internal waves. A technical challenge in carrying out the experiment is the high-precision, relative navigation, positioning and control between the two AUVs.

WORK COMPLETED

A preliminary trial was carried out in December of 1997 during which the Autosub and OEX were deployed off the coast of Ft. Lauderdale for a total period of 10 days. The underlying purpose of this trial was to explore the concept of concurrently using 2 AUVs, designed around different philosophies, to compliment each other on representative scientific data gathering missions. The process of organizing and running the trials, which included joint missions, would reveal the short-comings and the needs for joint operation, such as that proposed for Scotland in the Summer of 1999.

During the synoptic mission, the entire set of navigation data, CTD data, lightsheet data and water samples were collected. During December '97 trials, he following accomplishments were achieved for the Autosub:

- First deployment outside the UK.
- First mission run concurrently with another AUV for synoptic data gathering.
- Successful integration of ADCP into vehicle navigation.
- Deepest deployment (210 m).
- Longest deployment (110 km, 19 hours).
- Successful terrain following in complex reef environment.
- Successful co-operation between FAU/USF/NOVA/SOC.
- Successful long tows in difficult conditions.

A new self-contained turbulence measurement package has been developed and was mounted on the Autosub and used to make small-scale turbulence measurements in the Sargasso Sea near Bermuda in August 1998 (see Figure 1). The collected data are currently being analyzed.

Data collected using the Autosub.

During all the missions data was logged from the 3 CTDs onboard, from the Ph sensor and the ADCP, along with all the engineering data. The data will be analyzed by the SOC team.

Data collected using the Ocean EXplorer (OEX) Series AUV.

The two missions involved surveying a 1km square region off the coast of Fort Lauderdale, on the edge of the Gulf Stream, where the water depth varies between 12m and 36m. The surveyed region lies between the second and third of the shallow longshore reefs found on the east coast of South Florida. The mission of December 5, 1997 was carried out at the location approximately 26^0 9.18'N, 80^0 4.61'W, while that of December 11, 1997 was carried out slightly south of this location, at approximately 26^0 8.01'N, 80^0 4.8'W, portions of the two regions overlapping.

The instantaneous position of the vehicle for the December 5th mission in terms of its latitude and longitude is shown in Figure 2. The instantaneous water depth recorded as a function of latitude and longitude during the six legs has been interpolated in Figure 3 to develop a bathymetry map of the surveyed region. The fairly flat, meandering "channel" between the reefs is apparent in the figures and is consistent with the known topography of the region. The density variations over the six legs, inferred from the recorded CTD data, are plotted in Figure 4 against the instantaneous longitudinal position of the AUV. For this mission, the ADCP was programmed to measure and record its velocity relative to a fixed frame and its velocity through the ambient water, but not to profile the velocity in the water column. Thus we can determine local currents. The variation in the horizontal components of the current over each leg, about the mean for each leg, is shown in Figure 5 and the data has been interpolated to show the regional current distribution in Figure 2.

Similar data have been obtained for the December 11th mission; the ADCP also provided velocity profiles for this mission. The measurements contrast well with those of December 5th, which were taken during the passage of a cold front over South Florida. A paper based on this work presented at the UUVs98 and a corresponding journal paper is in preparation.

IMPACT/APPLICATION

The proposed work will provide important oceanographic data for development and establishment of dynamics models for Langmuir circulation and internal waves, which in turn have strong implication on littoral environmental assessment, such as transport of heat, gas and momentum from near-surface to mid-water layer, acoustic propagation due to cell scattering effect, and mixing mechanisms in a stratified water columns.

TRANSITIONS

The success of the joint missions will lead to other collaborative missions with the Autosub, for example in the Mediteranean.

RELATED PROJECTS

1 – Remote Sampling and Survey of Shallow Water Using AUVs with Application to Mine Reconnaissance (ONR).
2 – Sampling and Survey with AUVs in Adverse Weather Conditions (ONR).
3 – AUV Navigation and Platform Development (ONR).

PUBLICATIONS

1. *Regional Oceanography using a small AUV*. E. An, M Dhanak, S Dunn and S Smith. UUVs'98. Southampton, England. September, 1998. Full Paper.

Figure 1. The turbulence package mounted on the Autosub during trials in Bermuda (August, 1998)

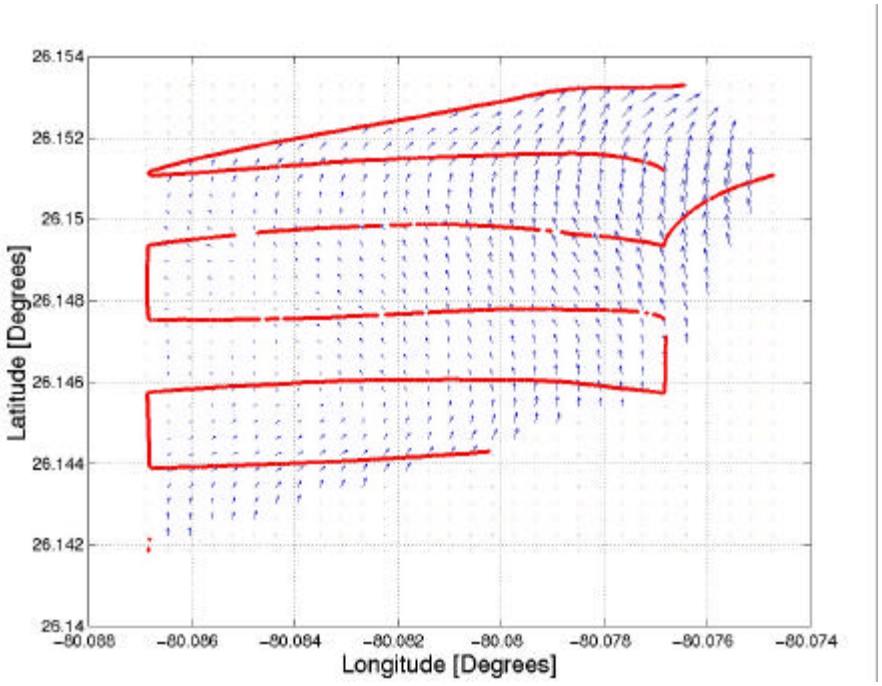

Figure2. Path of OEX and local currents during December 5, 1997.

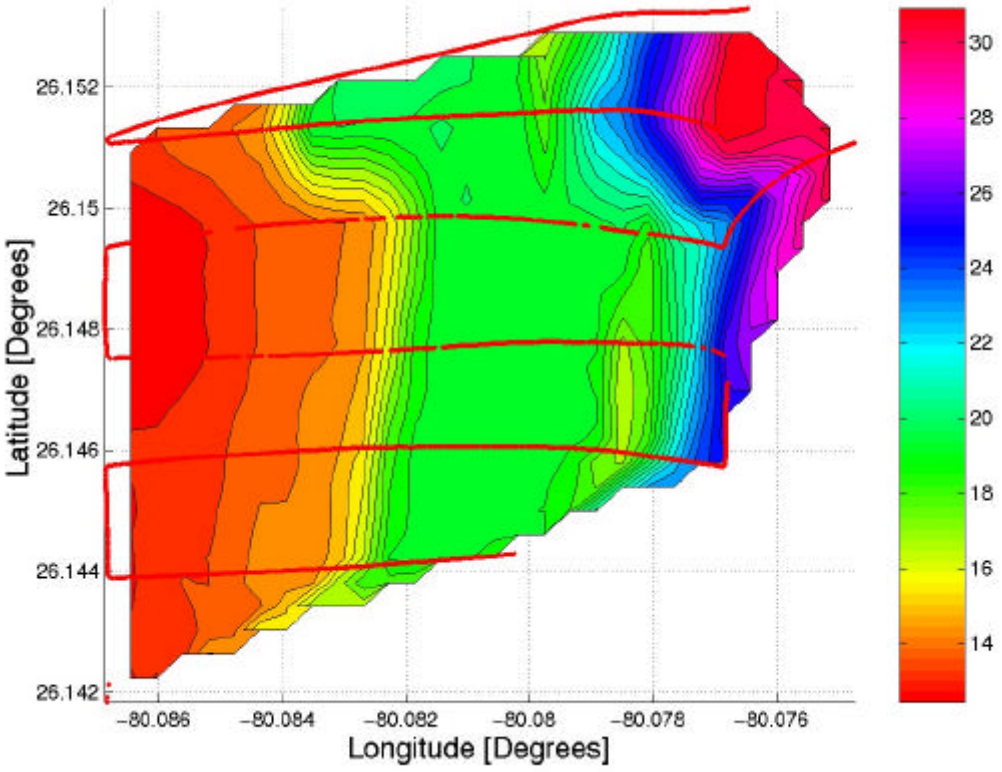

Figure 3. Regional Bathymetry determined from measurements by the OEX.

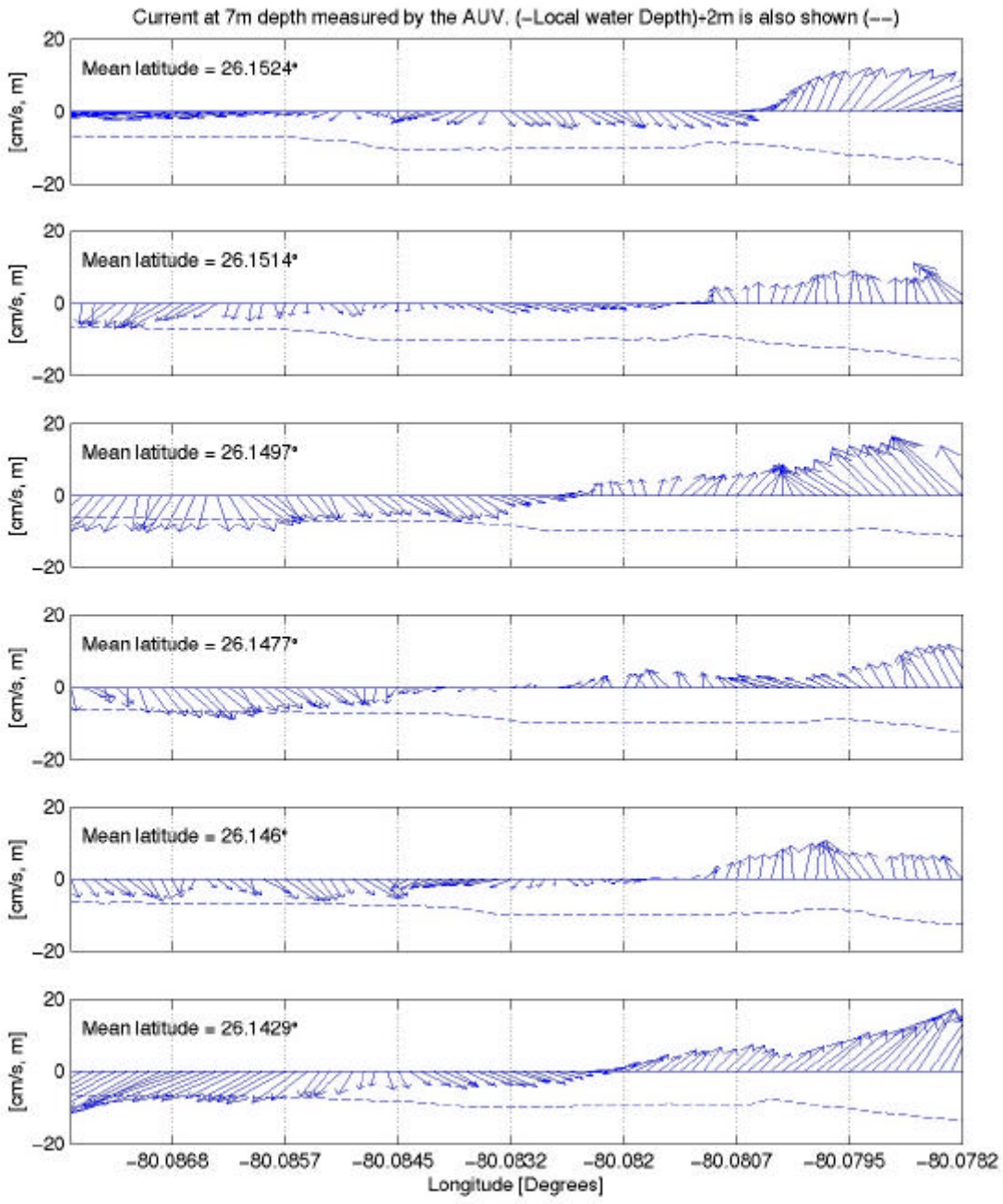

Figure 4. Local currents measured by the OEX on December 5th, 1997.

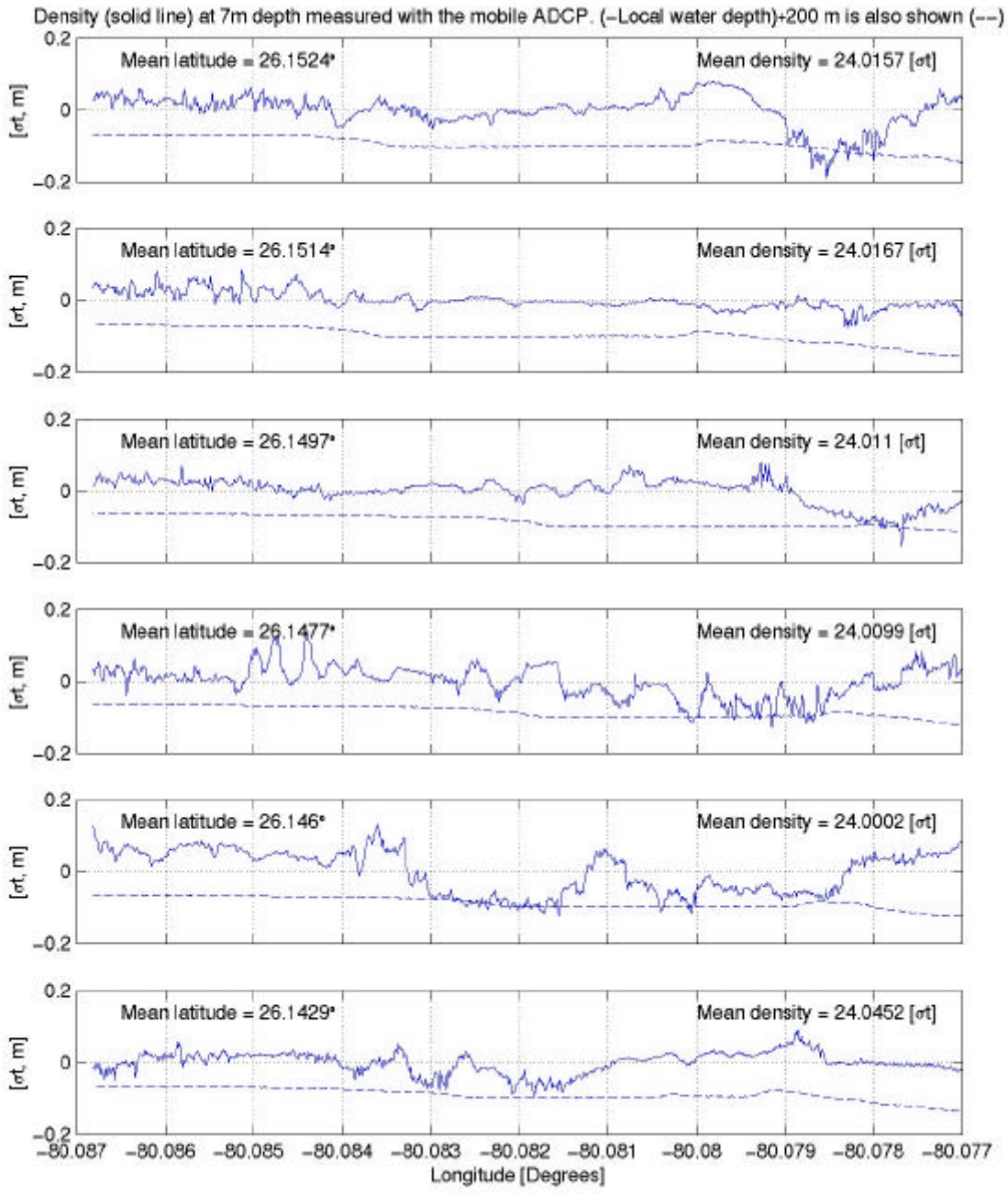

Figure 5. In-situ density variations inferred from CTD measurements by the OEX on Dec. 5, '97.